**U.S. Army Corps
of Engineers
Seattle District**

DRAFT ENVIRONMENTAL IMPACT STATEMENT

Centralia Flood Damage Reduction Project

Chehalis River, Washington

General Reevaluation Study

SKOOKUMCHUCK DAM RE-OPERATION REPORT

APPENDIX B

July 2002

Skookumchuck Dam Flood Operations Agreement

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1.0 Introduction

1.1 Background and Objectives

The U.S. Army Corps of Engineers (Corps) and Lewis County are reevaluating solutions for flood control in the Chehalis Valley. There are several flood control strategies being analyzed but common to many is the need to modify operations at Skookumchuck Dam which may require new outlets, increased storage and new discharge guidelines (Appendix A).

The objective of this document is to provide engineers, sponsors and other interested parties some discussion of the potential environmental impacts associated with these proposed modifications and to provide some related recommendations. The need to develop a reoperation plan based on the dam modification alternatives presented will be an integral part to the overall success of the project. For the purposes of this report, all impacts and recommendations will be based on Alternative 2B2, which is most likely to be chosen as the preferred alternative (Appendix A).

Skookumchuck Dam was constructed in 1970 and is owned by a consortium of public and private utilities. Pacific Power and Light operates the dam to provide water supply for the 1400-megawatt Centralia Steam Electric Plant and to supplement flows for fish resources. The steam plant receives its maximum allotment of 54 cfs from an intake structure located on the left bank at approximately river mile (RM) 7.51.

Skookumchuck Dam is a central core rolled earthfill structure 190 feet high, 1,340 feet long with a dam crest elevation of 497 feet. Its spillway is an ungated structure with a capacity of 28,000 cfs at its spillway crest elevation of 477 feet. Its reservoir covers a 540-acre area with a 35,000 acre-feet capacity at the full pool elevation of 477 feet. The outlet works consist of two concrete encased steel pipes cut in rock under the dam. The outlet capacity is 150-220 cfs with control satisfied by two 24-inch Howell-Bunger valves.

The dam has a multi-level intake system located at elevations 449, 420 and 378 feet that allows water temperature below the dam to be maintained at less than 60^{o} F for fish resources. A portion of the water is used by the Washington Department of Fish and Wildlife (WDFW) for a fish rearing facility approximately 0.5 miles downstream of the dam.

Hydropower was installed at the dam in 1990 when a small powerhouse was constructed adjacent to the outlet structure near the original stream channel. Water is supplied from the outlet conduit to a horizontally mounted Francis turbine with a 1MW capacity. Discharge from the turbine is routed to the natural channel via a gravel-lined channel approximately 450 feet long.

2.0 Existing Operations (WDFW/PacifiCorp Agreement)

2.1 Skookumchuck Dam

Skookumchuck Dam currently operates on a fill and spill regime. The reservoir fills each year with the first heavy rains of the fall and then allows all subsequent inflow to spill uncontrolled over the dam until summer when the reservoir lowers as inflow drops.

The existing flow management agreement between PacifiCorp and WDFW for Skookumchuck Dam was completed in May 1998 and is intended to provide benefits to downstream fish resources and the needs of the Steam Plant. There are also provisions for steelhead production and other requirements unrelated to water control. The agreement specifies minimum flows throughout the year, water temperature objectives, reservoir elevations, as well as water use limitations and general guidelines for ramping, coordination and operations. There is no existing flood control capacity at the dam. In the summer, inflow drops off and causes the reservoir to lower until such time the fall or winter rains arrive and fill the reservoir.

Water discharge from the outlet tunnel is dependant on reservoir elevation. As the reservoir rises and reaches each intake, the corresponding outflows adjust on a continuum from 95cfs with one outlet submerged, 140 cfs with two outlets submerged and as much as 220 cfs with all 3 outlets submerged. After the reservoir fills, discharge is passed both through the sluiceways and over the spillway. Although it varies each year, monthly outflow averages generally range between 95 cfs and 1200 cfs depending on the month. During high flow conditions, discharge from the dam can greatly exceed monthly averages with a 5-yr event passing 4,000 cfs and a 100-yr event passing 7,425 cfs.

3.0 Flood Control Operations (Reoperations)

3.1 Flood Control Operations

Modifications to Skookumchuck Dam as outlined in alternative 2B2 are intended to support limited flood control operations at Skookumchuck Dam. Specifically, reservoir operations will change to allow drawdown in the fall to elevation 444 by early November. It is anticipated that this flood control capacity will remain until a flood event occurs. During a flood event, outflows from the dam will be reduced in order to prevent flow at the Pearl Street gage in Centralia from exceeding 5000 cfs. Depending on the magnitude of the event, discharge will be limited to no more than 3,000 cfs. After the event passes, water stored in the reservoir will be released at volumes high enough to reach but not exceed 5,000 cfs at Pearl St. Discharge from the project would be via two new 8-foot by 11-foot slide gates located on the dam with a bottom elevation of 436 and a common discharge tunnel entering into the existing spillway on the right bank (Figure 1). The gates purpose will be to pass flood flows throughout the flood season. The maximum storage pool elevation will be 492 and would require the use of a 15-foot high rubber or steel weir added to the spillway crest. The 15 foot high spillway structure would be inflated or dropped into place only during events that would require use of the additional flood control storage. This additional storage would be reserved for floods above the 70-yr event and not fully utilized until around the 100 yr event.

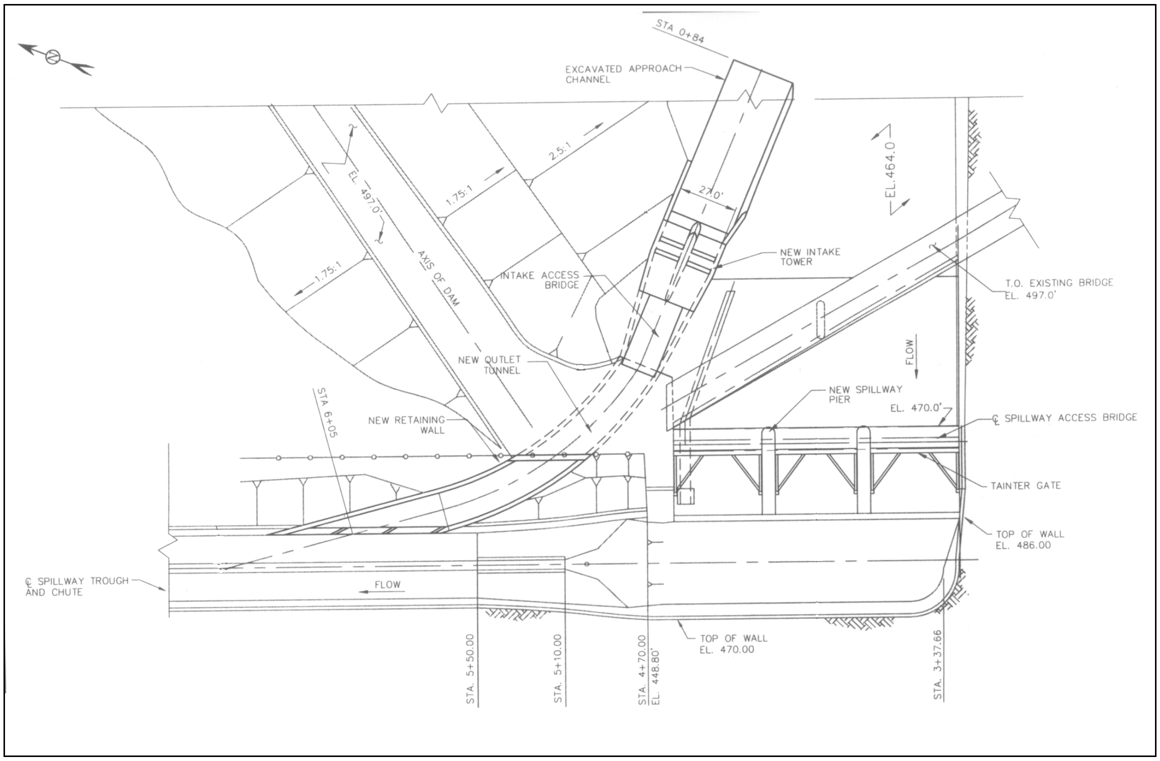

Figure 1. Proposed Skookumchuck Dam Outlet Structure and Spillway Modifications

3.2 Routine Operations (Post Construction)

In the absence of a flood, Skookumchuck Dam is expected to operate for the benefit of both PacifiCorp and the natural resources of the river. However in the existing operations guidance, not all areas of routine operation are clearly described. For instance, there is little discussion of proper ramping rates. The WDFW/PacifiCorp agreement of May 1998 simply states: “Flow reductions under this Agreement shall be accomplished in a manner that minimizes the stranding of juvenile fish”. Specific criteria were not provided initially because the bypass reach between the dam and its hydropower unit was so short and no other opportunities to significantly modify flows existed at the dam. With the installation of flood control capability however, large changes in river stage will become possible.

Other Western Washington flood control projects were reviewed to develop more specific guidelines. This review revealed that both up and down ramping should contain restrictions based on the season and fish resources. With the exception of special operational needs, routine ramping rates between projects were reasonably consistent (Table 1).

White River

Season	Direction	Time	Rate
Feb 15 June 15	Up	Day	1”/hr
		Night	1”/hr
	Down	Day	No ramping
		Night	2”/hr
June 16 Oct 31	Up	Day	1”/hr
		Night	1”/hr
	Down	Day	1”/hr
		Night	1”/hr
Nov 1 Feb 14	Up	Day	1”/hr
		Night	1”/hr
	Down	Day	2”/hr
		Night	2”/hr

Howard Hanson Dam

Season	Direction	Time	Rate
Feb 16 May 31	Up	Day	No ramping
		Night	2”/hr
	Down	Day	No ramping
		Night	2”/hr
June 1 Oct 31	Up	Day	1”/hr
		Night	1”/hr
	Down	Day	1”/hr
		Night	1”/hr
Nov 1 Feb 15	Up	Day	2”/hr
		Night	2”/hr
	Down	Day	2”/hr
		Night	2”/hr

Table 1. Ramping Rate Criteria from Selected W. Washington Projects.

In addition to the ramping rates for routine operations as identified above, several specific criteria were described for times of flood control or sensitive spawning periods. For instance, ramping rate guidelines for Mud Mountain Dam are more flexible during times of flood control where the tailwater elevation may increase as much as 1 foot/hour. It is however, specifically requested that great consideration be given to public safety prior to changes of that magnitude. At Howard Hanson Dam, special ramping criteria are given during the steelhead spawning and incubation periods (April- July). To protect eggs incubating in redds near the river margins, ramping is not allowed to alter river stage greater than 1’ below the highest average mean daily flow for the previous 10 days.

3.2.1 Reservoir Operations

Post-project reservoir operations will be tied primarily to flood control where a requirement will be in place to ensure the reservoir elevation is at or below 444 prior to the onset of the flood control season in early December. During the summer to fall drawdown period, flows from the project will be passed through the outlet structures such that the reservoir lowers to elevation 444. When drawdown is complete, inflow will be passed through the outlet works to maintain reservoir elevation so long as flows at Pearl Street remain under 5,000 cfs. It is expected that project discharges would meet or exceed the minimum instream flows of 90 cfs except if reservoir inflow fell below 90 cfs. The reservoir should remain relatively constant throughout the late spring, summer and early fall. In winter, larger reservoir fluctuations may occur as the project reacts to flood events and the reservoir fluctuates between elevations 492 and 444.

3.2.2 Downstream Flows

Flow operations for Skookumchuck Dam during non-flood events will be similar to the operation that is in place today. Except for flood events, post-project outflows should continue to follow historic outflows as recorded by the Bloody Run gage located slightly downstream of the dam (Table 2).

The Bloody Run gage shows wide flow variations through the years. In general, daily discharge trends show flow increasing from a low of about 100 cfs in the late summer (August) to a mean monthly flow in January and February around or exceeding 1000 cfs. This pattern can vary widely by year although the summer month regimes are quite consistent.

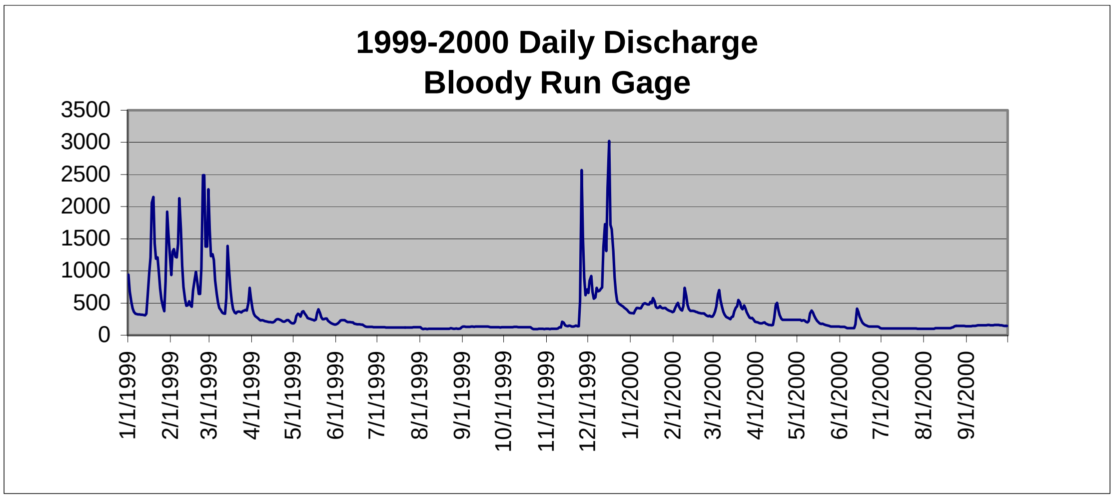

Table 2. Daily Discharge at Bloody Run for 1999 and 2000.

Maximum flows can be much higher than the average mean of around 1000 cfs. During flood season, high water releases of between 2000 and 3500 cfs are not uncommon. These events tend to be relatively short in duration lasting around 4-6 days. Bankfull flows in the upper reaches below the dam occur at discharges of 3,000 cfs.

4.0 Natural Environment

Skookumchuck Dam, the reservoir and river are located within the Chehalis Basin of Southwest Washington. The river originates from the west slope of the Cascade Mountains in the Mt Baker Snoqualmie National Forest, and drains approximately 183 square miles. The upstream portion of the river flows through heavily forested hills while the remainder of the river flows through a broad, flat valley. Near the confluence with the Chehalis River, the Skookumchuck River is impacted by human development and floodplain modifications. Flows for the river are dictated primarily by rainfall. The upland and riparian landscapes are dominated by a mix of coniferous forests of Douglas fir and western hemlock, and deciduous forests comprised of bigleaf maple, alder, cottonwood and other plants.

4.1 Physical Environment

4.1.1 Gravel Distribution

The Skookumchuck River is dominated by gravels and cobbles, with larger cobbles and boulders present to a lesser extent (PIE 2001). Fine sediments (sands, silts, and clays) are sparsely distributed throughout, however they are found more frequently in the middle reaches where gradients are lower. Larger cobbles and small boulders are more frequent in the upper and lower reaches.

During field investigations, coarse to very coarse gravels were observed to be the dominant channel substrate type within the Skookumchuck River (PIE 2001). The upstream half of the river below Skookumchuck Dam is dominated by coarse gravels, with areas of fines and larger cobbles also present to a lesser degree. The downstream half of the river below the dam is predominately small to medium-sized cobbles, interspersed with areas of fine sediment and larger cobbles and boulders. Coarse gravels are also present in this area.

4.1.2 Water Quality

Water quality within the Skookumchuck River is generally considered adequate for sustaining aquatic resources but it does have a history of degradation. Historic water quality problems stemmed from logging practices and industrial runoff, which caused low dissolved oxygen, elevated water temperatures and high turbidity. Today however, most dissolved oxygen issues have been addressed and water temperature is regulated by cold water releases from the Skookumchuck reservoir. Turbidity has also been reduced in the mainstem but it still remains as a principal concern in Hanaford Creek, a tributary to the Skookumchuck. Hanaford Creek is also on the Washington State Department of Ecology’s 303(d) list for elevated levels of fecal coliform, which is presumed to stem from heavy agricultural activities adjacent to the creek. The high coliform levels are augmented by other areas along the river and arrive at the mouth between late summer and winter (Table 3). Low summer flows have also caused some problems in the river but these are primarily a natural function arising from the small drainage size and little contribution from snowmelt.

Date	Time	Temp (deg C)	Flow (CFS)	Oxygen Satur. (%)	pH (pH)	Suspend Solids (mg/L)	Turbidity (NTU)	Fecal Colif. (#/100ml)
10/29/96	1150	8.9	185	85.8	7.2	8	11	150
11/25/96	1215	6.4	722	81.5	6.5	35	32	960
12/16/96	1520	5.3	910	84.7	6.9	7	10	17
1/28/97	1515	4.1	594	87.4	6.7	8	17	22
2/26/97	1450	6.1	517	89.2	7.1	5	9.5	26
3/26/97	1230	9.3	475	90.4	7	7	11	9
4/30/97	1320	9.4	467	87.9	7.4	6	7.3	33
5/28/97	1445	14.8	169	94.3	7.5	3	3.8	55
6/24/97	1250	14.2	194	95	7.5	4	5.6	92
7/30/97	1510	16.4	360	99.6	7.6	3	2.6	16
8/27/97	1420	13.9	195	94.7	7.6	3	3.6	110
9/30/97	1300	13.3	210	88.1	7.3	3	3.4	150

Table 3. Skookumchuck Water Quality Data, 1997 (RM 2.3).

4.1.3 Side Channels

During recent field surveys, side channel habitat was documented in thirteen of thirty-three reaches surveyed below Skookumchuck Dam (PIE 2001). The majority of the side channels are located in the upper and lower reaches of the river; however urban development along the Skookumchuck through Centralia has diminished the capacity for side channel habitat in the lower reaches of the river. Side channel habitat is an important habitat feature, providing crucial life history functions such as rearing and holding habitat for fish, and overwintering habitat for migrating waterfowl.

4.1.4 Vegetation

The vegetation community within the lower Skookumchuck subbasin is typical of an area highly developed for agricultural uses. Narrow riparian corridors and cleared agricultural fields dominate the area. Riparian vegetation, while present in some locations, is highly fragmented by high densities of roads and rail lines throughout the region. Urban and industrial development adjacent to the lower reaches of the Skookumchuck further limit the presence and function of vegetative cover.

The tree component of the riparian canopy along the Skookumchuck River consists mainly of hardwoods such as black cottonwood, big leaf maple, and red alder (PIE 2001). Conifers such as western red cedar and Douglas fir are also present to a lesser extent. The dominant shrubs are red osier dogwood, snowberry, and various willow species, while groundcover is dominated by reed canary grass and Himalayan blackberry.

4.1.5 Wildlife

Wildlife populations throughout the Skookumchuck subbasin below the dam are composed mainly of species associated with open forest canopies and young vegetation. Currently, the predominant land use along the Skookumchuck River is agriculture, with industrial and high density residential dominating the lower reaches in and near the city of Centralia. Consequently, wildlife populations within these areas are characterized by those species most tolerant of human activity such as deer, black bear, and cougar. Furbearers also present include beaver, muskrat, raccoon, mink, river otter, and opossum (PIE 2001).

Several WDFW priority wildlife species have been documented in the Skookumchuck subbasin. These priority species include: bald eagle, eastern wild turkey, great blue heron, harlequin duck, hooded merganser, osprey, pileated woodpecker, western gray squirrel, Edith's checkerspot, and wolverine (PIE 2001). Urban and agricultural development throughout the subbasin has significantly reduced the habitat available to these and other wildlife species. Therefore, though some of these species were sighted in the area historically, those such as the wolverine are not expected to be present.

4.2 Aquatic Environment

4.2.1 Fish Distribution

Fish utilization of the Skookumchuck River is different above and below the dam. Steelhead trout currently use the areas above Skookumchuck Dam for spawning and rearing. Adults are captured at a trap and haul facility located at the base of the dam using protocols and guidelines developed under an existing agreement with WDFW. The reservoir and upper river are also used by cutthroat trout for spawning and rearing.

Below the dam, fish resources include spring and fall chinook, coho salmon, winter steelhead trout and anadromous and resident cutthroat trout. Chum habitat exists but the natural salmon run is considered extinct from the Skookumchuck. There is a coho fish rearing facility located about 1/2 mile downstream from the dam. The facility's water supply is obtained from the dam's outlet works and delivered to two large rearing ponds by pipeline. Bull trout have not been observed in the Skookumchuck River below the dam, and only one juvenile has been captured in a WDFW trap on the lower Chehalis River in 1997, indicating the presence of anadromous bull trout in the Skookumchuck is doubtful. Olympic Mudminnow have been sighted in Hanaford Creek, a tributary of the Skookumchuck, as well as many other small resident fishes.

4.2.2 Spawning Habitat

Anadromous spawning habitat is abundant throughout the Skookumchuck River below the dam, and was documented in all but three reaches during recent field investigations (PIE 2001). As mentioned above, larger gravels and cobbles are more frequent in the lower and upper reaches of the river. This trend coincides with the prevalence of anadromous spawning gravels in the lower and upper reaches of the river, where gravel sizes are generally larger.

Areas of resident spawning are also present throughout the Skookumchuck, although to a lesser extent. Resident spawning gravels are expected to be more abundant throughout the middle reaches where gravel sizes are generally smaller due to areas of lower gradient. Numerous tributaries, such as Hanaford and Johnson creeks, also provide spawning habitat for various resident fish species as well as coho salmon.

4.2.3 Rearing and Holding Habitat

Rearing and holding habitat is also abundant in the Skookumchuck River below Skookumchuck Dam. Generally, rearing and holding habitat is most abundant in the upper and lower reaches of the river; however during recent field investigations rearing and holding habitat was found in all but three reaches surveyed (PIE 2001). The most common physical feature by which rearing and holding habitat is provided is large woody debris (LWD). LWD functions as holding habitat by providing cover from predators and high temperatures as well as scouring out pools in the channel bottom. As mentioned above, side channels also provide important rearing and holding habitat throughout the Skookumchuck, located mainly in the upper and lower reaches. Side channels offer important rearing habitat for juvenile salmonids by providing protection from predators and swift currents and also by providing valuable food resources.

5.0 Impacts to Natural Environment from Existing Operations

The existing flow management agreement between PacifiCorp and WDFW outlined above provides guidelines for flow maintenance throughout the calendar year as minimum allowable flows. Ramping rates, which are unspecified in the existing agreement, are intended to avoid adverse affects on fish populations within the river channel. This report reviews both positive and negative impacts from the presence and existing operation of Skookumchuck Dam. Impacts have been separated into those related to reservoir operations, passage through the dam and downstream impacts from flow operations.

5.1 Skookumchuck Reservoir

5.1.1 Reservoir

The existing “fill and spill” dam operations result in seasonal fluctuations in water surface elevations. The largest fluctuations are those related to refill and drawdown of the dam during which the reservoir fluctuates 37 feet between elevations 440 (462-425) and 477 (PacifiCorp, 2002). Refill begins around the first week of November (late October - early January) and is usually completed by January 1 (late November – late January (Figure 3, USFWS PAL 1989)). Drawdown occurs naturally as the dry summer weather causes inflows to decrease. The reservoir begins to recede from the shoreline at el. 477 around mid June (mid May – late June) and continues to drop until the following fall when weather patterns increase inflow (Table 4).

	Average Elevation (1970-1999)	Minimum low-pool within data set
Sept. 01	459.6	451.2
Sept. 15	453.9	445.8
Oct. 01	447.7	436.9
Oct. 15	442.8	426.1
Nov. 01	443.0	426.1
Nov. 15	451.5	422.0
Dec. 01	462.4	424.0

Table 4. Water Surface Elevations in Skookumchuck Reservoir

These fluctuations over time have created a 16-foot varial zone (461-477) within which significant vegetation around the reservoir shoreline has been eliminated (USFWS PAL 1989). Visible during low pool, the varial zone is diverse in its composition, ranging from bare basalt cliff to wide mud flats (PIE 2001). In the summer, grasses appear to colonize limited areas of exposed mud and soil around the reservoir and some pocket wetlands or ponds may also be created in flat areas as the reservoir recedes. In the period between reservoir drawdown and summer vegetative growth, there is a potential for exposed mud flats to erode into the reservoir and create locally elevated turbidity levels. These levels may be measurable immediately below the dam but overall turbidity levels appear quite low (Table 3).

The reservoir is at full pool between late winter and spring and not usually before December. During this period, the water surface is adjacent to the vegetated shorelines of the reservoir. This is particularly important to small salmonids, which need the shoreline cover and prey production during their early rearing period. Amphibians and other small animals may also benefit from the reservoir being at full pool in the spring. In the summer however, fish and other aquatic resources are denied the shade, productivity, and shoreline cover afforded by vegetation. During this time, reservoir fish resources most likely rely on benthic food production, zooplankton, small fishes and terrestrial prey for nourishment as well as prey input from tributaries. Amphibians and other water dependant riparian species may be impacted in the summer if wetland connections are reduced.

5.1.2 Reservoir Tributaries

Tributaries of the reservoir, including the mainstem Skookumchuck River, are affected by existing reservoir operations. While productivity of the reach may have improved overall by the addition of the reservoir, some aspects of the reach have suffered.

Principally, reservoir inundation of the three major tributaries has resulted in the loss of potential steelhead and resident trout spawning habitat. Fall Creek, Turvey Creek and the Skookumchuck River have all seen some degree of sediment deposition at their mouth. Excess sediment accumulation renders the extreme lower reaches of tributaries in a state of constant degradation. Additionally, as the reservoir rises in winter, bedload moving in the tributaries drops at the shoreline and results in delta formation, which can affect fish passage. Even though the lower reaches of the tributaries have been impacted by the reservoir, the tributaries still provide a valuable function for aquatic resources. It appears that fish passage is still possible at all the major tributaries. Additionally, summer prey contributions from the tributaries may be particularly valuable to juvenile and adult fish. Fish access to upper benthic communities and terrestrial input is often reduced as the reservoir recedes from vegetated shorelines and upper reservoir benthos is desiccated. Zooplankton contribution to the diet of reservoir fishes is unknown but may be a significant source given the summer reservoir drawdown.

5.2 Skookumchuck Dam

The staff at Skookumchuck Dam have already taken steps to reduce impacts on adult and juvenile anadromous fish from dam operations. The dam currently operates a juvenile fish passage chute and a trap and haul facility for steelhead. Discussions with WDFW have indicated that the juvenile passage structure is adequate for passing steelhead smolts under most conditions. The system works best at full pool; during drawdown, the juvenile steelhead have more difficulty accessing the bypass chute and flume system. Adult fish passage by trap and haul is reserved only for adult steelhead migrating upstream of Skookumchuck Dam. The fish are collected at a weir system downstream of the dam and transported above the reservoir where they are released into the mainstem. The hauling program also provides the fish access above a natural partial blockage in the form of cascades at the head of the reservoir.

The dam has a series of sluiceway gates located along the dam that serve to regulate temperature and are the principal source of discharge during drawdown and in the summer months. These sluiceways extend through the dam and are regulated by Howell-Bunger valves on the downstream side. The elevations of these gates (449, 420 and 378 feet) are between 28 and 100 ft below the water surface. Gate submergence between 60-80 ft is within the potential for smolts to find and utilize them for downstream passage (Dilly and Wunderlich, 1992; Dilly 1993). It is not known what percentage of juvenile steelhead pass through the sluice gates but passage through Howell-Bunger valves is likely to reduce passage survival. Smolt passage over the dam does not appear to significantly impact survival.

Since dam construction, sediments moving into the reservoir from the upper basin have likely been trapped by the reservoir. Some of the small materials (suspended fines) exit the project, but some of the material remains in the upper reaches and low pockets of the reservoir. This sediment accumulation may provide a benefit by reducing the turbidity downstream during fill and spill operations but it may also act to prevent gravel contribution to the downstream spawning locations. Examples of this can be found in the reach below the project where substrates appear to be biased towards larger material. However, it appears that downstream gravel contributions from tributaries and bank erosion, makeup for dam impacts within 1800 ft of the dam. Whether sediment movement impacts will continue in the long term or become significant is difficult to predict.

5.3 Skookumchuck River

Water releases from Skookumchuck Dam have a great effect on the biological communities between Skookumchuck Dam and the Chehalis River. The manner in which the dam is operated affects fish rearing habitat, spawning habitat, wetland connectivity, vegetative succession and wildlife habitat. Dam discharges contribute greatly to erosion and deposition and drive bedload movement through the system. The dam operation guidelines control water temperature to the benefit of native fish and establish minimum instream flows for the benefit of the river and adjacent ecosystems (Table 5).

September 1 through October 31	Minimum instream flow of 140 cfs for spawning fish
November 1 through March 31	Minimum flow of 95 cfs for incubation period
April 1 through August 31	Maximum flow of 95 cfs or natural flow plus 50 cfs, whichever is less.
Water temperatures must be maintained at 50^{o}-55^{o} F to the maximum extent possible.	

Table 5. Existing Dam Operations Guidelines

5.3.1 Summer Flows

Instream flows were negotiated between WDFW and PacifiCorp in 1998 for the adequate protection of instream resources. Summer flows are managed at the dam through the use of three existing sluice gates. Depending on the reservoir level, appropriate sluice gates are opened to provide adequate temperature and flow volumes. The water released travels downstream and picks up local inflow to RM 7.23 where the steam plant intake removes a maximum of 54 cfs from the instream flows. Local inflow contributes approximately 50 percent of flow to the Skookumchuck River (Table 6).

	Maximum Flows							
	2 yr	**5 yr**	**10 yr**	**25 yr**	**50 yr**	**100 yr**	**200 yr**	**500 yr**
Dam Outflow	2996	4078	4891	5918	6542	7424	8197	9268
Flow measured at Mouth	5434	7361	9360	12243	14072	16649	18676	22038
Difference (Contribution from Tributaries)	**2438**	**3283**	**4469**	**6325**	**7530**	**9225**	**10479**	**12770**
Percent flow contributed by Reservoir	*55*	*55*	*52*	*48*	*46*	*45*	*44*	*42*

Table 6. Mainstem and Tributary Flow Contributions to the Skookumchuck River

Existing dam operations assist in keeping water temperatures within reasonable limits during late summer. When the reservoir drops below full pool and ceases spill, the water is then drawn from lower outlet gates, which act to quickly drop water temperatures. Elevations in water temperature through the system are then driven in part by lack of riparian vegetation and the contribution of high temperature water from the tributaries; however temperatures still remain relatively low (Table 3). Tributaries are also a source of high fecal coliform (Hanaford Creek) which contributes to the coliform loading in the Skookumchuck River, particularly in the late summer and early fall.

Summer low flows from Skookumchuck Dam are regulated to provide a maximum of 95 cfs between April and August for coho, steelhead and chinook rearing. After September 1 the flows are increased to a minimum of 140 cfs, primarily for spring chinook spawning, and maintained until October 31. Other fish returning to the river at that time include fall chinook, coho, chum, winter steelhead and resident trout.

After October 31, the project is allowed to pass natural inflow, which generally hovers around 150-220 cfs until the first fall rains of November. With the first heavy rainfalls of November, the reservoir inflow exceeds the capacity of the existing sluice gates and the reservoir fills quickly.

5.3.2 Refill

During the fall, inflow from increased precipitation surpasses the ability of the sluice gates to pass water causing the reservoir to fill to the spillway elevation of 477 within a period of 2-4 weeks. When the reservoir is full, all inflow in excess of the sluice gates discharge capacity (approx 220 cfs) spills uncontrolled over the spillway. This “fill- and-spill” operation offers limited flood control capacity since the reservoir is typically full prior to the big flood events of winter. However, allowing the spill to occur provides a nearly natural hydrograph for spawning, incubating and rearing salmonids in the river. Some off-channel habitats dependant upon higher flows may remain unavailable until after refill is complete. When the winter floods occur after refill, they are passed down the Skookumchuck River to meet the floodwaters of the Chehalis River. During the refill period, increased flow from moderate freshets in the upper Skookumchuck are absorbed by dam storage and do not reach the lower river during salmon migration. These freshets have been found elsewhere to be a trigger for upstream migration. A reduction in freshet occurrence may cause some salmon to extend their migration timing. It is not known whether this altered flow regime causes excessive delay in adults. The winter fill-and-spill regime continues for as long as inflow exceeds the sluice gate capacity.

5.3.3 Flood Events

Under current operations, the reservoir typically fills prior to the onset of winter high flows. Therefore capacity is full when the high flows begin causing all inflows to be passed over the spillway into the downstream reaches of the Skookumchuck River. Flooding impacts from existing operations on aquatic resources are similar to those of unregulated streams including the potential for excessive redd scour as bedload is eroded from confined or steep sections of the river. The existing operations cause high flows on the Skookumchuck River to frequently overtop its banks with mixed impacts to adult and juvenile salmon. Overbank flooding in areas of extensive mainstem connectivity (as evidenced by the presence of side channels, unconfined banks, wetlands and creeks) increases the potential for overwintering use by salmonids and the probability that salmonids can return to the mainstem on the descending hydrograph. Overbank flooding in areas of limited mainstem connectivity (as evidenced by levees, human development and agriculture) may provide overwintering habitat but lowers the probability of salmon returning to the mainstem on a descending hydrograph, which then raises the concern for stranding.

5.3.4 Drawdown

Drawdown is a natural event triggered by a reduction in inflows above Skookumchuck Dam as a result of summer weather patterns and is typically completed by mid-June. The most noticeable effect of drawdown is the presence of stable water releases at 220 cfs, which are reduced methodically as the reservoir drops below the invert of the higher sluice gates. As the reservoir drops and exposes each gate, the capability of the dam to pass water downstream is reduced. This decrease in discharge continues until only the gates at elevations 420 and 398 are operable and the summer flow regime begins.

Since the act of drawdown is a natural event dictated by reservoir inflow, the impacts to the Skookumchuck River downstream of the dam mimics those of natural rivers of similar composition. These may include dewatering of late spawning salmonids and stranding juvenile fish in off-channel ponds as the waters recede. Since the duration of drawdown in the Skookumchuck River is prolonged salmon can usually adjust to drawdown coverage and the effects of drawdown are minimal.

6.0 Impacts to Natural Environment from Flood Control Operations

6.1 Skookumchuck Reservoir

6.1.1 Reservoir

The flood control project proposes a 15-foot high weir or gate structure to be used only during floods approaching the 100 yr event. The control structure would engage for flood protection only and cause the reservoir to rise above the historic full pool elevation of 477 towards a new elevation of 492. This would cause floodwaters to inundate a variety of upland and wetland habitats including basalt cliffs, talus slope, steep brush and timber slopes, shallow slopes and vegetated lowlands. Depending on the magnitude of the flood, the additional pool would increase between 1 and 15 feet above the existing full pool and remain above elevation 477 between 1 and 3 days (28-69 hours). The operations would occur in winter, when vegetation is dormant. The infrequent occurrence should allow inundated vegetation to survive and keep the varial zone within its current elevations. However, increased sediment deposition in the newly inundated vegetation may affect growth rates. It is anticipated that the timber and underbrush between elevations 477 and 492 will remain intact although an increase in woody debris recruitment would occur as a result of the higher pool.

The increased size of the reservoir during large flood events would be most noticeable at the head of the reservoir where mainstem habitat would be inundated; however the inundation would not extend above the cascades located at the head of the reservoir. The extent of lost habitat from this additional mainstem inundation is not likely to be significant given the timing of the events, the current spawning habits of steelhead and the infrequent nature of the flooding.

Flood operations under the proposed project would produce more frequent fluctuations of the winter reservoir. The proposed project calls for the reservoir to be evacuated through the new outlet gates after each flood event to reclaim flood storage. Under existing conditions, the reservoir is allowed to fill and remain stable until inflow decreases in the spring. The proposed project would strive to keep the winter pool at elevation 444 and therefore reduce the availability of shoreline vegetation to riparian animals and aquatic resources until February, when the pool would be allowed to refill. Keeping the reservoir away from the shoreline during the lean winter months will make prey contributions of the tributaries and mainstem much more important. In addition, the lower reservoir may increase the opportunity for cutthroat trout to prey upon juvenile coho and steelhead. The reduction of the winter pool to elevation 444 may also cause some of the accumulated sediment within at the reservoir to mobilize as the reservoir draws down during high inflows. Similarly, pool fluctuations during winter would expose an incremental area of reservoir edge, exposing sediments to rain and other weather events. To the extent that these sediments enter the reservoir, some degree of increased turbidity could be expected. Any incremental increase in turbidity would likely be passed downstream but it is unclear whether it would be significant over the normally low background levels of the Skookumchuck River.

6.1.2 Reservoir Tributaries

Under the proposed project, impacts to tributaries would be similar to those described in the existing condition but with the addition of varial zone erosion. Since the reservoir remains evacuated during the winter, tributary channel flows moving through the unconsolidated and exposed soils of the varial zone may result in some downcutting and erosion. Consequently, tributary passage for resident fishes during the winter may become a concern. Also within the varial zone, the potential for sedimentation, woody debris movement and channel alteration may also create fish passage issues. However, high tributary flows would likely continue after the pool elevation is raised, reducing the potential for changes to tributary channel maintenance processes. Loss of spawning habitat from an increase in reservoir elevation is not a significant issue since most steelhead spawn upstream of the reservoir and the mainstem gravels between elevation 477 and 492 are too large for trout spawning.

6.2 Skookumchuck Dam

Modifications to the dam under the flood control project include a multitude of small structural changes as well as the addition of a weir structure and additional low level outlet gates. Impact from structural modifications would be limited to concrete work in and around the dam. Concrete pouring, drilling and mixing can have impacts to fisheries and wildlife by raising pH levels of water if conducted in small poorly circulated aquatic environments or if the mixing components are allowed to enter the water in large quantities. Since most of the construction is conducted upland and the Skookumchuck River is large enough to ameliorate the effects of curing small concrete projects, the likelihood of experiencing harmful levels of elevated pH is very low. The weir and sluiceway construction would have similarly low levels of direct harm related to their construction.

Operation of the proposed flood control weir should also be limited in its potential impact. The weir would be employed only during the largest events to provide the extra reservoir storage space needed. It is not anticipated that the new dam crest would be overtopped so fish passage over the structure would be eliminated. Special attention should be paid to fittings and structural supports to ensure they reduce potential injury to fish that pass.

The current flood control plan includes construction of 2 outlet gates for the purpose of improving discharge capacity. The existing project does not have the ability to pass inflows larger than 220 cfs until the reservoir fills and water is released over the spillway. The new outlet gates will allow for discharges between 1500-3000 cfs depending on the operating plan. The gates would be fitted with drop gates for control. A new tunnel would be created through the dam and allowed to reconnect into the existing spillway on the right bank. The increased discharge capacity in winter would markedly change the flow fields at the dam. With the inclusion of a flood control project, all flows would be passed through the new larger gates and likely influence fish migration pathways through the dam. Since flow is a primary factor for passage selection, some percentage of steelhead and resident trout moving through the dam between November and February would likely travel through the new outlets even if access to the spillway was available. In the winter however, fish passage would be limited to some adult steelhead that fall back after transfer, and resident trout. Anadromous out-migration occurs after the flood control season. Still, design of the outlets should be conducted to minimize or avoid impacts to fish passage with particular attention taken to the outlet reconnections to the river. In addition, the reservoir spillway and outlet gates should be closely co-located to avoid the potential for splitting flow fields and causing a delay in whatever migration is occurring.

6.3 Skookumchuck River

6.3.1 Summer Flows

The summer flows and temperature requirements under the flood control agreement will continue as outlined in the existing WDFW agreement. After the flood control season, there are no current plans to actively manage inflow for summer flow augmentation. Summer water quality will remain similar to the existing condition. A rule curve for summer augmentation flows has not been developed and falls outside the scope of this effort.

6.3.2 Refill

Under the existing agreement, the refill period results in constant outflows after the reservoir is full, usually in November. Prior to full pool, initial freshets are captured in the reservoir until the water surface elevation reaches the spillway crest; at which point they are passed over the dam. The proposed project would not allow the reservoir to refill in winter. The early freshets that would normally be captured in the reservoir would be passed to maintain a reservoir elevation of 444. These freshets are considered to have positive effects on fish migration. Adults moving upriver may use inflow pulses caused by fall rains to begin moving toward their spawning grounds. Once at the spawning grounds, these freshets may also help initiate spawning. Juveniles rearing in the river may also use fall freshets to begin moving into side channels and other overwintering habitat prior to the onset of winter.

Downstream of the reservoir, the proposed project will result in downstream flows that are more variable. Under the existing agreement, discharges during the refill period gradually ramp up to a flow of around 220 cfs and remain there until refill is complete and excess flows are passed over the spillway. The proposed project has the capacity to provide more variation in outflow during the existing refill period assuming it is supported through adequate inflow. The proposed project also acts to delay refill until the end of the flood season. Under the proposed project, refill is tentatively scheduled between March 1 and April 15. Impacts on the biological community from the proposed project would be highly dependant on the operational ability of the project to provide the increased winter inflows. It is assumed the reservoir will be managed to maintain the minimum pool in anticipation of floods, which would result in most freshets being passed quickly. If the flood control operation calls for capture of the freshets until the pool has filled to a critical point, than the benefits of the freshets would be diminished.

Downstream, late fall flows could have impacts to spawning salmon depending on the duration of high flow events. If freshets are captured and then released over an extended timeframe, redds built by salmon on high gravel bars may be at risk of desiccation, commonly a problem in spring when high flows are less likely to keep higher elevation redds watered. Also, if the modified hydrologic regime allows for extensive and frequent connections to side channel complexes and other off-channel rearing areas, the dam operations could benefit rearing juvenile salmon. The shift in refill from November to April may have some undetermined affects on reservoir prey dynamics. However significant impacts are not anticipated as the pool will remain full prior to outmigration and prior to significant spring vegetation and invertebrate production.

6.3.3 Flood Events

Flood events under the proposed project will represent a change from the current condition. Existing operations do not mitigate downstream flooding once the reservoir is full, causing frequent overbank flows. The proposed project will store the peak of flood flows behind the reservoir and release water to maintain flows of less than 5,000 cfs at Pearl Street in Centralia. The result will be the elimination of large overtopping events as they are replaced with smaller events of greater frequency and duration. Sediment routing and timing may also change with this project.

In other Western Washington rivers, overbank flooding in areas of poor river connectivity is considered to constitute a significant risk of adult and juvenile salmon loss. In most urbanized and altered river systems, overbank flooding does not allow for adequate return pathways to the river. The result is often juvenile and adult salmon stranded in pasturelands, roadside ditches and suburban neighborhoods with no mechanism for reentry to the river. Under natural conditions, where reaches have good connectivity by way of small tributaries, extensive side channel habitats or wetlands, overtopping events represent rearing opportunities for juvenile salmon and provide refuge for adults to escape the turbulent, debris filled mainstem. Field investigations along the Skookumchuck found most tributaries had good connectivity to the mainstem but there were few mainstem reaches with connected side channel habitat and floodplain connectivity (PIE 2001).

Confining large flows of sufficient velocity in the channel can also create the long-term hazard for channel instability. In river systems with good floodplain connectivity, overtopping is common and acts to undersize the width and depth of the mainstem.

Flood scour energies are dissipated over the floodplain, slowing the channel forming processes. An increase in the duration and amount of flows within the main channel can destabilize the current channel configuration, resulting in excessive erosion of banks and accelerated gravel accumulation in the flatter areas of the river. Side channel habitats of the lower gradient reaches (for example, around Bucoda) may be degraded if sediment dynamics change and significant accumulations occur. Confined reaches of the river may also see accelerated redd scour from similarly altered bedload characteristics.

LWD recruitment is another important consideration for in-channel flow. Overbank flooding can lift both LWD and coarse woody debris from outside the channel and can weaken ageing trees, increasing the likelihood of toppling. A decrease in overbank flooding would more likely move woody debris already in the channel further downstream without bringing new material into the bankfull width.

6.3.4 Drawdown

Drawdown under the proposed project would remain a natural event. As precipitation decreases in the spring and summer months, the required outflow (95 cfs) usually draws the reservoir surface elevation down below the spillway crest. The addition of the outlet gates could provide more flexible outflow regulation depending on the needs of the river but the use of these gates outside the flood season would rely upon water availability, instream flow requirements and maintenance constraints.

7.0 Recommendations (Proposals for an Operations Plan)

Beyond describing and identifying potential biological benefits and impacts of providing flood control at Skookumchuck Dam, it is the goal of this report to propose a plan for operating Skookumchuck Dam. The operating plan developed here is designed to take into consideration the environmental conditions at the site and provide for their protection. The recommendations below are proposed for consideration and review in the hope that they provide a basis for operating Skookumchuck Dam for the highest practical protection of biological resources.

7.1 Flood Control Rule Curve and Discharges

The development and adoption of a rule curve is a major operational feature associated with the addition of flood control at Skookumchuck Dam. The rule curve guides decisions on dam releases during flood control operations as well as guiding the rate of reservoir evacuation. The rule curve also serves as a guide for refill and drawdown planning. Since a rule curve affects reservoir elevation and downstream releases so significantly, it should be developed with consideration for biological resources.

Initial discussions with hydrologists at the Corps resulted in the development of a provisional rule curve based on initial review of flood control data and the biological information provided in earlier sections (Figure 2). While it is not a formal and binding rule curve, it does provide a proposal for the protection of biological resources. The provisional rule curve was based on the following assumptions

- Flood storage drawdown to provide at least 11,000 acre/ft.
- Refill initiated based on water forecasts but completed by April 1
- Drawdown initiated when inflow to reservoir is less than instream minimums or when necessary to ensure drawdown by target date of October 31.
- Minimum instream flows are 95 cfs (Nov 1 - Sept 9) and 140 cfs (Sept 10 - Oct 31).
- Minimum pool is 455.
- Maximum pool is 477.

Based on the information available at the time of this report, it is recommended that the provisional rule curve be used as a starting point for hydraulic evaluation. Although it is recognized that the final rule curve may deviate from this provisional rule curve, the curve is considered to be consistent with the most significant biological needs of the system and where changes are made, the rational for the deviation should be documented.

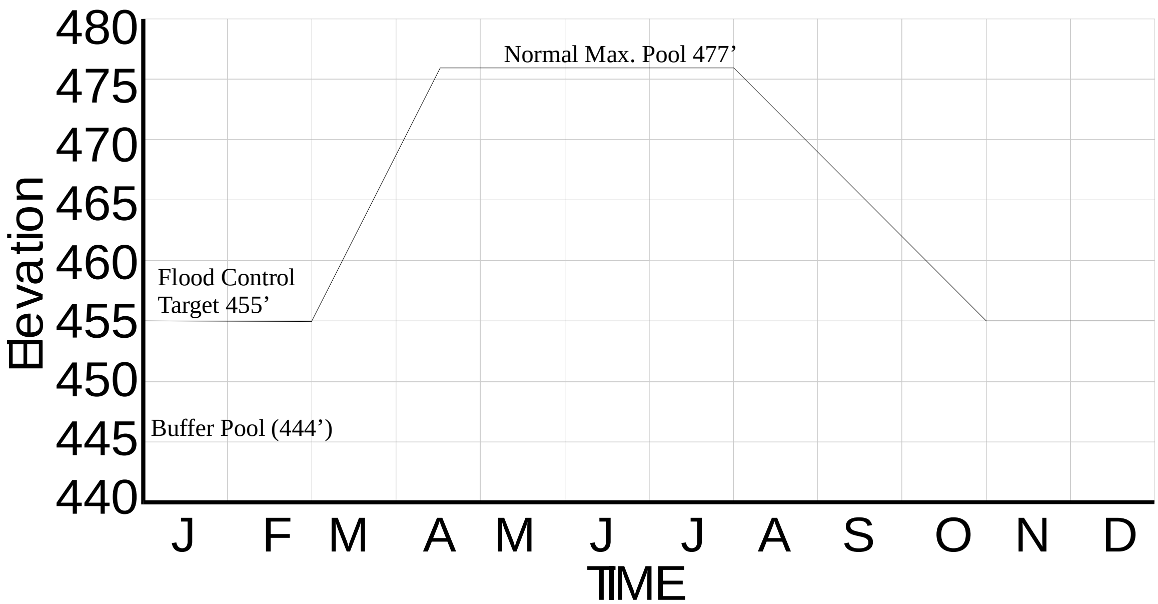

Figure 2. Provisional Rule Curve for Skookumchuck Dam

7.1.1 Maximum Flows

Rule curves are paired with flood control objectives and forecasted inflows to regulate discharge from the dam for the purpose of managing high flow events. For the Skookumchuck River, discharges above the 2-yr event are captured within the reservoir and held to ensure the Pearl St. objective of 5,000 cfs is not violated. After the peak of the high flow event passes, stored water is released to remain within the Pearl St. objectives until the reservoir is evacuated and ready for the next event. The evacuation of the reservoir adds additional flow to the end of each event extending bank full flows beyond the baseline condition. The impacts of this are described in earlier sections, but it appears there are two significant physical considerations when managing these high flows. First it is critical that the existing gravels and fines be allowed to continue moving towards the Chehalis River. Bedload movement and channel scour processes are critical to maintaining spawning gravels, woody debris recruitment, undercut banks and other mainstem habitats. Secondly, it is critical to ensure that the reduction in high flows to levels at or below the 2-yr event will allow for adequate maintenance of important off-channel habitats.

Groundwater Recharge

A concern identified on the Chehalis River that warrants some review here is the role of peak flows on the recharge of freshwater aquifers and perhaps wetlands. The concern arose originally from uncertainty in the role of overbank floodwaters on the Chehalis River. It was considered possible that the characteristics of the Chehalis River floodplain biased it towards a need for winter overbank flooding to recharge groundwater resources. In reviewing the differences between the large system characteristics of the Chehalis to the smaller Skookumchuck River, it appears that overbank flooding on the Skookumchuck River has not been an important factor in the maintenance of its sub-basin. The large volume of tributary input, frequency of local flooding and location of most adjacent wetlands appear to indicate that the sub-basin approaches or exceeds groundwater saturation without the addition of winter and early spring flooding events. As such, the role of additional floodwaters during these months does not appear to significantly add to the ability of the sub-basin to absorb water and add additional water volume to the sub-basins' surface and groundwater resources.

Should additional information be presented that indicates that groundwater or surface water resources of the Skookumchuck River basin are inadequate for the provision of its vegetative and aquatic resources, then it would be recommended that a groundwater or other recharge study be developed and implemented to ensure the proposed project is able to meet the basins' needs. It is further recommended that no levee structures be constructed that limit the ability of the 2-yr event to interact with the existing floodplain (Appendix B). Continued overbank flooding at the 2-yr level will maximize interaction between high water levels and upland habitats.

Bedload Movement and Channel Processes

Bedload characteristics of the Skookumchuck River are predominantly gravel and cobble. The results of pebble counts done in 2000, showed no clear trend except that larger substrate types were found closer to the dam and finer materials tended to show up down towards the mouth or in flat reaches such as near the town of Bucoda (Figures 3 and 4)

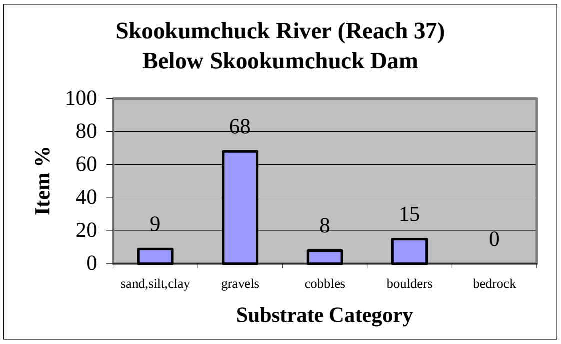

Figure 3. Pebble Count Data at Reach 37

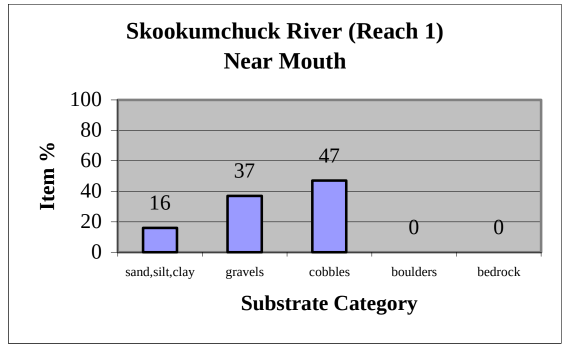

Figure 4. Pebble Count Data at Reach 1

The distribution of substrate after the proposed flood control operations are in effect will be linked to the rivers ability to recruit and move material downstream. The flood control project proposes limiting downstream discharge to the 2-yr flood event which represents a restriction to higher flows from the existing condition. The pebble count data from the Skookumchuck River appears to indicate that Skookumchuck Dam may be restricting some gravel recruitment from the upper watershed but that the input of gravels from tributaries such as Bloody Run Creek, Hanaford Creek and others are currently providing gravel adequate for spawning by anadromous fish. The size and distribution of the gravel appears to be small enough to allow mobilization and transport at moderate to small flood flows such as the 2-yr event, although more information may be needed to confirm this. Although it is less clear whether the 2-yr event will allow for enough movement often to prevent gravel build up at tributaries' mouths. While this is a common problem in small to medium-sized tributary systems, the Skookumchuck appears large enough to make the 2-yr flood flow potential (3,000 to 5,000 cfs) sufficient to move the gravel size common within its banks and manage the deposition potential at the mouths of the tributaries.

Similarly, the 2-yr event is expected to continue the processes of erosion on unstable and unconsolidated banks. Also, the reduction in peak flows may lengthen residency times for woody debris which will likely offset initial limitations to woody debris recruitment from reduced flood discharges.

Based on the above information, it is recommended that the proposed project allow the 2-yr event be passed and not stored for flood control or other purposes. The 2-yr flood events appear vital to the maintenance of the Skookumchuck River channel and may be particularly necessary in the Bucoda reaches. It is further recommended that no levee structures be constructed that limit the ability of the 2-yr event to deposit and erode channel materials.

<u>Off-channel Rearing Habitat and Wetlands.</u>

Off channel habitats and adjacent wetlands of the Skookumchuck River are generally concentrated between two areas below the dam; between the base of Skookumchuck Dam and Troller Run Creek (RM 17.4-21.4), and also between the confluence of Hanaford Creek and the Town of Bucoda (RM 3.8-7.5). Development and agriculture have been consistent with habitat development in these areas. Within these reaches, side channels and wetlands are associated most frequently with low lying benches and ancient gravel bars. They range from degraded reed canary grass swales to higher quality habitats with extensive deciduous overstory and diverse plant communities. Most of these off channel rearing habitats and adjacent wetlands appear to be connected to the river at normal low flows and almost all of them are likely connected at bank full flow where they are watered by the Skookumchuck River, Chehalis River backwater, or tributary inflows. However, any off channel or wetland habitats that may rely upon high flows for creation, connection or maintenance will have fewer habitat shaping events to continue the process.

It is recommended that the preferred project not prohibit normal winter flows and the 2-yr flood event from reaching the existing off channel and wetland habitats. It is further recommended that existing habitat be identified and protected as the formation of new habitats through flood events may be diminished with the flood control project.

7.1.2 Minimum Flows

Minimum flows are dictated by the ability of inflow to support the existing summer requirement of 95 cfs. In most years, inflow appears capable of meeting or exceeding this standard. When minimum flows are elevated to 140 cfs between September 1and October 31, inflows are not always able to meet the demand. The impact of this lies principally on adult chinook salmon which migrate upstream during this time. Inadequate flows during this period may increase travel time and decrease the availability of spawning habitat. WDFW has informally expressed an interest to improve flows between September and October from 140 cfs to 160 cfs to ensure adequate flows for adult chinook. The difficulty rests in getting additional water without impacting resources during other times of the year. The provisional rule curve provides for drawdown to October 31 thereby allowing flexibility to provide some additional water during this period depending on water availability and reservoir management. Additional efforts are needed to provide insight into the reliability of providing additional water in the late summer.

An engineering study should be conducted to investigate the possibility of storing water to allow an additional release of 20 cfs to increase the minimum flows between the months of September 1 and October 31. It is recommended that this study include discussion of impacts to flows elsewhere during the year and the reliability of providing the water. It is also recommended that the existing minimum flow criteria of 95 cfs be maintained and not reduced in support of this action.

7.2 Ramping Rates

An expansion on the limited guidance given in the PacifiCorp and WDFW agreement appears to be warranted. The operation plan recommends using guidance from elsewhere to ensure river levels are manipulated such that they minimize concerns over fish stranding or spawning impacts, but no specifics are given.

In reviewing projects with established ramping rate criteria, it appeared the ramping rates reflect a high degree of consistency, giving some confidence that ramping rates could be transferred between projects and remain adequate for resource protection (Table 7). There are however, discrepancies within our examples. Differences were seen in the areas of winter daytime ramping rates as well as spring ramp up rates (both daytime and nighttime). Also, the seasonal calendar is different between the two projects with the dates June 1- June 16 included in the spring period for the White River.

For the calendar discrepancies, it is recommended that the early June period remain within the spring ramping period to ensure ramping rates are sufficient for late outmigrating steelhead. Similarly, it is recommended that conservative daytime spring ramp-up rates be adopted for the protection of juvenile salmonids. It is also recommended that a 2”/hour ramping ability in the nighttime be allowed for quicker maintenance operations and minimal disruption to steelhead spawning.

Season	Direction	Time	Rate
February 15-June 15	Up	Day	0”/hr
		Night	2”/hr
	Down	Day	No ramping
		Night	2”/hr
June 16-October 31	Up	Day	1”/hr
		Night	1”/hr
	Down	Day	1”/hr
		Night	1”/hr
November 1-February 14	Up	Day	1”/hr
		Night	1”/hr
	Down	Day	2”/hr
		Night	2”/hr

Table 7. Recommended Ramping Rates for the Skookumchuck River

7.3 Upstream Fish Passage Operations

Upstream fish passage operations are limited to the passage of adult steelhead around the dam between the months of September 15 and November 15. The option to haul coho and chinook remains open but the current focus is to rebuild steelhead populations before allowing additional salmon above the dam. In addition, most spawning habitat for chinook was lost through the creation of the reservoir. The operation is conducted at a fish trap located at the base of Skookumchuck Dam. The trap appears to be adequate for its purposes. The need to provide access to the productive habitats of the upper Skookumchuck watershed is recognized and it is proposed that the operation continue with one modification.

To ensure the adult steelhead continue their upstream travels with a minimum of disruption, it is recommended that they be transported and released above the upper end of the reservoir. The release site should also be maintained to minimize injury and fallback. It is also recommended that the transfer truck be maintained in good condition with proper aeration equipment.

7.4 Downstream Fish Passage Operations

Downstream passage occurs primarily between the months of April 15 and May 31 with juvenile steelhead as the only anadromous outmigrant. To date, there are no other juvenile anadromous salmon above the project. The existing downstream passage plan for Skookumchuck Dam relies heavily on a full pool condition arising prior to the onset of outmigration. Full pool allows outmigrants access to the spillway and the fish passage chute, both designed to pass fish via surface flow down the spillway and into the river below. During periods of use, the outlet gates are also a potential source of exit for the outmigrants. They are located within a reachable depth but probably don't exhibit enough attraction to induce many fish to use the outlets for passage. A new gate located adjacent to the dam would likely attract more fish than the existing outlet gates.

Based on the need for a full pool to pass juvenile fish most successfully, it is recommended that the pool be refilled at the end of the flood control period or no later than April 1. This condition should be allowed to continue until natural inflows cause the reservoir elevations to drop. It is critical to design any new outlet gates and tunnels such that safe fish passage through that structure can be assured. In years of drought, the reservoir may refill slowly or not at all and increase the use of outlet gates for outmigration. Similarly, the potential for forecasting late flood events may cause the reservoir to remain evacuated, delaying refill and increasing the use of outlet gates for outmigration.

7.5 Vegetation

7.5.1 River Channel

Potential effects to river channel vegetation are primarily due to the lack of overbank flooding at flows above 3000 cfs at the dam and 5000 cfs at the mouth. Vegetation reliant upon flows under these levels should continue without harm and may even increase as high flows are moderated during floods. Of particular concern is the loss of the larger overbank events and its affect on future woody debris recruitment. Canopy resources located at elevations directly accessed by larger floods would become unavailable. This loss of recruitment potential could result in an overall decrease in the amount and diversity of large woody debris found throughout the river making the existing riparian corridors along the river even more important.

To reduce the impacts of these effects on the riparian community, some level of overbank flooding would be necessary. It is recommended that overbank flooding be allowed to continue as they relate to flood flows less than the 2 yr event (Appendix B). Recharging wetlands and off channel areas with overbank flows is important in maintaining the present species diversity and vegetative community structure within these areas. Allowing overbank flows in certain areas would also serve to mobilize woody debris from the riparian corridor and deposit it into the riverine system. A such, it is recommended that no levee construction be allowed that inhibits areas of overbank flooding in areas of off channel or wetland habitats below the 2 yr event.

7.5.2 Skookumchuck Reservoir

An increase in the maximum pool elevation of the reservoir would have several potential effects on the vegetative communities surrounding the reservoir. The primary vehicle for vegetative effect would be related to elevated pool levels during large flood events (70-100 yr events). During these large events, the reservoir elevation would begin to rise above the existing limit of established reservoir vegetation. If conducted for extended periods of time (30-60 days) or during the growing season, the effect could be the loss of upland vegetation near the shoreline. If affected, vegetative reestablishment will take some time to complete and be further hampered if the pool is allowed to inundate the vegetation zone after the start of the growing season (March 15-October 1). The effect would be to reduce canopy, vegetative diversity, nearshore shading and wildlife use. The reservoir will also be allowed to fluctuate below elevation 477 on multiple occasions throughout the flood season. This activity should not have significant affects to established shoreline vegetation.

To reduce the impacts of these affects, it is recommended that the frequency of reservoir pool elevations above the existing shoreline vegetation limits be conducted only during the months of October 1 – March 15 to lessen the impact on the existing vegetation. It is further recommended that the reservoir be managed such that the vegetation is not affected (pool does not exceed elevation 477) for more than 10 days. Additionally, it is recommended that pools above 477 not occur more than four times as often as could be predicted based on probability curves of the lowest flood requiring additional reservoir capacity. For example, once every 20 years if an 80 yr flood requires the pool to exceed 477 or once every 10 years if the additional capacity is required for a 40 yr flood.

7.5.3 Riparian Revegetation

As mentioned previously, the reduction in overbank flooding above the 2 yr event could cause the river channel to become more reliant upon the riparian corridor for sources of woody debris and terrestrial inputs as well as potentially slow the creation of additional side channel habitats. In addition, there are several stretches of the river and within the tributaries where the riparian corridor has been removed by human disturbance and agriculture or limited by heavy invasive growth or vegetation maintenance. To begin a comprehensive effort to remedy the riparian losses, it is recommended that an action plan for the sub basin be adopted or developed to identify and prioritize riparian corridor improvements for the benefit of the river. In conjunction, the action plan should identify regulatory and acquisition priorities to secure or improve good riparian habitat.

8.0 References

Black and Veatch. 2002. Independent Consultant Safety and Inspection Report. FERC Project No 4441. Completed in accordance with FERC Rules and Regulations, Part 12, Subpart D.

Bodurtha, T. 1989. Centralia Flood Damage Reduction Study, Planning Aid Report. Prepared for U.S. Army Corps of Engineers by US Fish and Wildlife Service, Olympia, Wa. 28p.

Dilly, S.J., and R.C. Wunderlich. 1992. Juvenile Anadromous Fish Passage at Howard Hanson Project, Green River. U.S. Fish and Wildlife Service, Olympia, Wa. 70p.

Dilly, S.J. 1993. Vertical Distribution of Juvenile Salmonids in the Forebay Area at Howard Hanson Dam. U.S. Fish and Wildlife Service, Olympia, Wa. 70p.

Pacific International Engineering (PIE). 2001. Fish, Riparian and Wildlife Habitat Study. General Reevaluation Report and Environmental Impact Statement. Pacific International Engineering, Tacoma, WA. November 2001

Washington State Department of Ecology. 1999. River and Stream Ambient Monitoring Report for Water Year 1997. Pub. No. 99-332. Washington State Department of Ecology, Environmental Assessment Program, Olympia.

Washington Department of Fish and Wildlife and PacifiCorp. 1998. Centralia Steam Electric Generative Project Fish and Wildlife Agreement. 9p.

APPENDIX A

Skookumchuck Dam Modification Alternatives

Alternative 2A - Authorized Project Feasibility Design
Studies in the early 1980s by USACE proposed modifications to Skookumchuck Dam to provide flood control and regulation. The initial proposal suggested a separate intake tower with an open channel tunnel in the right abutment along with addition of a 12-foot high steel bascule gate on the existing uncontrolled spillway.

Alternative 2B1 – Spillway Sluices with Gates and Rubber (or Steel) Crest Weir
A section of the existing ogee spillway would be removed and a new spillway section containing three gated sluices would be constructed. The three sluice gates would each be approximately 10 feet wide and 10 feet high. An emergency bulkhead would be installed to allow for dewatering of the gates.
The existing spillway approach channel is excavated in rock to an invert elevation of 464 feet. A trapezoidal-shaped channel, approximately 250 feet long, would be excavated within the existing spillway approach channel. The new sluiceway approach channel would have a bottom width of about 40 feet, an invert elevation of approximately 442 feet, and 1 horizontal (H) on 4 vertical (V) sloping sides. Approximately 10,500 cubic yards of rock would need to be excavated to construct the channel.
The discharge capacity of the existing uncontrolled spillway is approximately 28,000 cfs at the maximum design pool elevation. However, in a PMF discharge event of 32,500 cfs, the existing spillway crest would be submerged by water backing up from the spillway chute entrance. Modifications to the spillway would enable the use of the 15 feet of reservoir storage between elevation 477 and 492 feet for flood control and provide the PMF discharge capability. The modifications include adding a rubber or steel crest weir, modifying the ogee crest, and modifying a portion of the spillway chute.

A 15-foot high by 130-foot wide weir would be added to the existing spillway crest. The height of the weir can be varied through adjustment of the controlling structure. If necessary, the weir can be quickly raised in the case of a steel gate or deflated in the case of a rubber weir to allow for unrestricted flow of water over the spillway. Deflation of the weir is carried out automatically so that the weir is inherently safe under all conditions.

The existing spillway chute is located in a rock excavation on the left abutment. The chute bottom converges from a width of 40 feet to 25 feet and has 1H on 4V side slopes. The walls are concrete lined 7 to 13 feet vertically above the invert, with excavated rock side slopes above the concrete lining. During the PMF discharge, the water surface in the chute would overtop the concrete lined portion of the walls, but would still be contained within the excavated rock channel. This rock material has been identified as being highly fractured and susceptible to freeze-thaw damage. In order to protect the rock portion of the chute, the rock slopes would be lined with shotcrete up to the PMF water surface profile. The invert of the plunge pool below the spillway ogee crest would also be excavated out and lowered to make room for the new spillway sluices.

Alternative 2B2 - Short Tunnel with Gates and Rubber (or Steel) Crest Weir- Preferred Alternative
This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a short tunnel constructed in the rock forming the left abutment of the embankment dam. The intake would have two 8-foot by 11-foot slide gates. The tunnel would vary in shape from a 16foot diameter horseshoe to a 10-foot diameter conduit. Flow would discharge through the tunnel into the existing spillway chute.
The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top. The outlet tunnel would be designed to discharge up to 8000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway.

Alternative 2B3 - Tainter Gates in Rock Cut with Rubber Crest Weir
This alternative is similar to Alternative 2B2 described above. This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a channel constructed in the rock forming the left abutment of the embankment dam. The intake would have a single 16-foot wide by 15-foot high tainter gate. Flow would discharge through the channel into the existing spillway chute.
The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top. The outlet tunnel would be designed to discharge up to 8000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway.

Alternative 2B4 - Tainter Gates in Spillway Chute
This alternative would consist of an intake structure situated at the top of the existing spillway chute. The intake would have two 17-foot wide by 49-foot high tainter gates. The existing concrete overflow spillway would be removed and trapezoidal-shaped channel would be excavated within the existing spillway approach channel.

APPENDIX B

Pre-Project 2-Year Flooding Summary

Indicates water surface elevations higher than bank elevation.

	RM	Bottom El.	Water Surface.(ft)	Peak Flow (cfs)	Left Bank El.	Right Bank El.
Below Dam	21.77	335	347.78	2996	378	368
	21.54	332.5	341.46	2995.2	345	346
	21.31	330.5	337.05	2994.11	333	342
	21.05	320	333.08	3111.83	330	332
	20.7	317.34	328.34	3124.07	326	334
	20.65	319	327.48	3125.37	326	324
	20.6	318	326.38	3126.73	330	324
	20.3	312	321.8	3135.47	324	322
	19.8	306	316.51	3147.82	318	318
	18.97	298	306.91	3159.88	306	312
	18.56	294	304.57	3166.08	302	302
	18.34	291.3	303.28	3383.07	304	308
	18.33	291.3	303.17	3383.46	304	308
	18.32	291.3	303.13	3383.66	323.43	323.43
	18.31	291.3	303.13	3383.66	323.43	323.43
	18.3	291.3	303.06	3383.86	304	308
	17.52	285	294.73	3676.52	298	300
	17.51	285	294.34	3807.52	306	306
	17.5	285	294.34	3807.52	306	306
	17.49	285	294.48	3807.89	298	300
	17.1	281	290.94	3823.28	294	292
	16.65	276	286.74	3847.39	284	286
	15.83	269	280.23	3881.07	278	280
	15.81	269	280.13	3881.67	286	286
	15.8	269	280.13	3881.67	278	280
	15.34	266	276.77	3903.66	274	272
	14.92	261	273.71	3924.7	282	270
	14.57	255.5	268.64	3945.76	266	270
	14.56	255.5	268.38	3946.09	278.28	273.19
	14.55	255.5	268.38	3946.09	278.28	273.19
	14.54	255.5	268.44	3946.47	266	270
	13.97	250	262.75	3968.32	264	264
	13.5	245	258.43	4064.33	250	256
	12.85	240.2	254.21	4083.94	252	252
	12.46	238	252.11	4098.14	250	252

	12.2	236.3	249.74	4112.49	246	254
	11.92	235	248.48	4128.04	244	246
City of Bucoda	11.5	233.2	246.93	4129.26	247.2	248.4
City of Bucoda	11.2	229.7	245.79	4128.2	242.5	246.1
City of Bucoda	10.88	229.2	241.6	4125.86	248	248
City of Bucoda	10.87	229.2	241.46	4125.96	250.3	251.1
City of Bucoda	10.85	229.2	241.4	4126.01	250.3	251.1
City of Bucoda	10.84	229.2	241.38	4126.01	250.3	251.1
City of Bucoda	10.83	229.2	241.32	4126.05	248	248
City of Bucoda	10.56	227.8	238.59	4129.48	241.6	241.8
	10.1	223.7	236	4132.53	268.6	239.8
	9.83	220.3	234.61	4131.93	230.3	234.9
	9.81	219.8	234.41	4132.12	247.6	249.5
	9.8	219.8	234.39	4132.18	247.6	249.5
	9.78	218.8	234.38	4132.21	230.3	232
	9.39	218.4	231.75	4128.44	232.4	231.2
	8.95	214	228.63	4129.67	227.9	228.7
	8.52	210.5	226.08	4129.44	224.7	244.5
	8.05	209.5	223.37	4126.68	220.9	219.2
	7.66	206.3	222.07	4120.82	218.9	217.2
	7.32	208.7	218.67	4116.4	222	225.1
	7.31	208.7	218.25	4116.42	216.3	216.9
	7.3	208.7	218.13	4116.42	216.3	216.9
	7.29	208.7	218.07	4116.4	222	225.1
	6.98	203.4	214.22	4114.71	224.1	225.3
	6.64	196.5	211.65	4115.68	219.4	214.2
	6.44	197	208.62	4198.84	214	206
	6.43	193	208.47	4198.98	210	206
	6.42	193	208.46	4198.98	210	206
	6.4	194	208.2	4199.27	210	204
	6.38	194	207.94	4200.02	210	210
	6.17	194.6	207.28	4201.02	202.9	207.8
	5.85	192.7	205.15	4197.4	196.9	197.3
	5.79	188.6	203.82	4195.17	202	204.32
	5.44	187.5	202.64	4193.33	202	202
	5.08	186.5	200.89	4191.65	204	198
	4.83	185	200.36	4190.77	199.02	196.54
	4.82	185	200.28	4190.74	198.03	197.68
	4.81	185	200.27	4190.74	198.03	197.68
	4.8	185	200.1	4190.72	198	196
	4.54	186.6	198.78	4190.37	206	198
	4.25	184.1	196.72	4189.1	197.45	196
	4	182.6	195.41	4183.82	194	196

	3.85	179.5	194.77	4173.24	201.26	194
	3.84	179.5	194.77	5353.73	201.26	194
	3.54	177.8	192.98	5355.3	194	194
	3.32	177.8	190.48	5358.25	194	190
	2.99	175	187.75	5363.77	190	188
	2.85	174	186.81	5365.92	192	184
	2.43	171.3	183.97	5369.08	190	186
	2.42	171.3	184.04	5369.2	189.63	191.28
	2.41	171.3	184	5369.34	189.63	191.28
	2.41	171.3	183.91	5369.54	182.88	184
	2.21	170	182.19	5373.36	188	180.37
	2	170	180.2	5375.55	178	186
	1.57	163.1	175.3	5507.69	176	176
	1.56	163.1	175.13	5507.86	186.26	186
	1.55	163.1	175	5507.86	186.26	186
	1.55	163.1	174.93	5508.04	176	176
	1.51	160	174.54	5508.5	175.5	178
	1.5	160	174.43	5508.65	184	188
	1.5	160	174.32	5508.65	184	188
	1.49	160	174.26	5508.75	174	178
	0.98	157.5	171.31	5507.89	172	172
	0.77	156.4	171	5507.18	171.04	170
	0.64	154	170.37	5507.7	174.43	172
	0.62	154	170.11	5507.95	174	173.78
	0.61	154	170.07	5507.95	174	173.78
	0.59	151	169.97	5508.16	174.92	175.23
	0.49	151.8	168.18	5508.31	170	170
	0.24	153.6	165.42	5437.18	164	158.15
	0.22	153.6	165.12	5437.34	183.42	182.56
	0.21	153.6	165.1	5437.34	183.42	182.56
	0.18	153.3	165.15	5437.56	158.78	164
	0.03	143	164.89	5438.24	162	158
Mouth	0	143	164.85	5438.4	162	158